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ESCO business models for biomass heating and CHP: Profitability of ESCO operations in Italy and key factors assessment

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ABSTRACT

This paper describes ESCO approaches and business models for biomass heating and CHP generation. State of the art, policy measures and main barriers towards the implementation of such ESCO operations in Italy are discussed. Moreover, on the basis of the proposed framework, representative case studies in the Italian residential, tertiary and industrial market segments are compared. The case studies are referred to a 6 MWt wood chips fired plant. The case study of the industrial sector is based on a constant heat demand of a dairy firm, while in the tertiary and residential sectors the options to serve a concentrated heat demand (hospital) and a community housing by a district heating network are explored. The further option of coupling an organic Rankine cycle (ORC) for CHP is explored. The relevance of the research relies on the assessment of the main key factors towards the development of biomass-ESCO operations. The results of the techno-economic assessment show that the agro-industrial case study for heat generation is extremely profitable, because of the high baseline energy cost, the high load rate, the availability of incentives for biomass heating. The cogeneration option is also profitable, even if the higher investment cost determines a longer pay back time. The tertiary sector case study is also a profitable, for the presence of a concentrated load with high heat load rate and high energy cost. Finally, the residential sector case study is the least profitable, for the high district heating cost and the lower heat load rate, not compensated by the higher heat selling price. The higher investment cost of CHP, even if attracting further income from electricity sale, does not present higher profitability than the only heat generation plant. In addition, the heat load rate results a more influencing factor than the thermal energy selling price.

Contents

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1. Introduction

1.1. ESCO background

The increasing commitment toward climate change mitigation and the consequent implementation of policies for energy efficiency and renewable energy sources, together with the restructuring and liberalization of electricity and gas markets, are the major drivers behind increased interest in the provision of a wide range of energy services to final end users, such as energy efficiency measures, distributed generation technologies, and biomass technologies among them [1]. In this context, innovative utilities have recently moved towards offering added value through energy services, horizontally integrated and complementary to the traditional supply of energy. Other stakeholders, such as equipment and system suppliers, or installation and engineering companies, decided to enter the same market. Companies providing energy services to final energy users, including the supply and installations of energy-efficient equipment, building refurbishment, maintenance and operation, facility management, and the supply of heat/electricity, are known as Energy Service Provider Companies (ESPCs). Energy Service Companies (ESCOs) also offer these same services; however, an ESCO differs from ESPCs in one the following ways: (i) it can finance, or arrange financing for, the operation of an energy system, (ii) it guarantees the energy savings and/or the energy performances (as reflected in the contract), and (iii) its remuneration is directly tied to the results achieved [3–4]. Therefore, the ESCO risks its payments on the performance of equipment and services implemented.

The first overview of the European ESCO market was proposed in 2002 by Vine et al. [2], aimed at collecting information on the number of ESCOs, the key sectors targeted, the main barriers and the approximate value of projects conducted, in order to suggest possible actions to promote the ESCO industry. This study stated that ESCO-industry associations, financing, energy measurement and verification protocols, and information programs are some of the key factors for successful ESCO markets. Moreover, Countries putting emphasis on the removal of subsidies and privatization of energy industry are expected to lead the development of the ESCO industry. This review was followed by a series of comprehensive researches at EU level carried out by the European Commission's Joint Research Centre [3–5] and the ChangeBest project [6]. In particular, the research of Bertoldi et al. [3–5] draw attention to major differences in the development of the ESCO markets in EU to different levels of support offered by energy authorities, local market structures and rules, and variation in the definitions, roles and activities of ESCOs. It concluded that energy-efficiency projects offer a cost-effective approach to reducing greenhouse-gas emissions, and the emerging carbon markets will create new opportunities for diffusion of ESCO business. Another comprehensive insight of the European ESCO industry, trends in business practices and factors influencing their evolution was described by Marino et al. [7], on the basis of the results from a large-scale survey carried out in 2009–2010. The results show that, despite the increased awareness of energy efficiency measures, the ESCO market has only grown slowly during the past years, because of problematic access to finance, cross-subsidized energy prices, poor energy consumption data to build baselines. The relationships between ESCO activity indicators, as reported in [2], and country indicators (innovation index, GDP, energy consumption, CO_2 emission) have been assessed in [8], deriving information about size and orientation of the ESCO market. Outside Europe, the financial and cultural barriers of ESCO market in Japan and guidance for policymakers were discussed in [9], the evolution of the US ESCO industry was reviewed in [10], the barriers and opportunities of performance contracting in Hong Kong were discussed in [11], the alternative financing models for energy-efficiency performance contracting in Brazil were reviewed in [12], while the ESCO companies in northwest Russia in terms of legal issues and organizational schemes were described in [13]. In [14], Goldman et al. analyzed the US ESCO-market trends and activities over the last decade. It resulted that performance contracting overcomes market barriers for energy-efficiency investments among large,

institutional public-sector customers. In [15], a snapshot of US ESCO industry in 1998–2008 was proposed, reporting a growth of the US ESCO industry at about 7% per year between 2006 and 2008, with revenues of $ 4 billion in 2008 and net direct economic benefits for customers between 1990 and 2008 of about $ 23 billion. The results also show that ESCOs derive about 85% of their revenues from projects in the public/institutional sector, with payback time increased from 1.9 to 3.2 years in private sector projects since 1990s and from 5.2 to 10.5 years in public sector projects for the same time period.

1.2. ESCO and renewable/distributed energy

A more recent phenomenon is the concept of combining the benefits of performance contracting, under which the majority of ESCOs operate, with the benefits of "green technology", or "green performance contracting". Thus, ESCOs can deliver sustainable-energy solutions through performance contracting, extending their approaches from the end-user energy efficiency measures to the supply-side energy conservation ones. ESCOs that operate in the distributed and renewable energy field can thus deliver both sustainable energy (in the form of heat, cool and power) to suitable end-users and energy efficiency services, by means of the typical shared savings or guaranteed savings contracts, as discussed in the next chapter. A detailed framework of a mutually beneficial combination of ESCO and CDM (clean development mechanism) in developing countries is illustrated in [19], and an application to the adoption of distributed generation in a Chinese urban area (including gas/biogas CHP) is proposed to validate the approach. The rationale is that an ESCO can play an important role in pooling small-scale energy efficiency projects together, including decentralized renewable generation systems, in order to make them more attractive for support measures that require specific threshold investment levels (i.e. CDM projects, ELENA and JESSICA projects, Energy Efficiency Funds). When the environmental performances of the ESCO investments are valued in an economic manner, renewable technologies (such as biogas CHP [19]) become competitive in comparison to the more cost-effective natural gas CHP option. Further advantages of ESCO operations in pooling small-scale decentralized and renewable generation projects together are related to factors such as: (i) investment costs reduction for economies of scale, (ii) operational costs decrease for centralized plant maintenance, (iii) fuel supply savings when large stocks can be contracted in the wholesale market, (iv) possibility to balance supply and demand by a portfolio of centrally controlled micro-generation systems [20], (v) economies of scope for the provision of multiple energy services. An assessment of possible models for sustainable micro-generation investment and operation in the residential sector through energy services co-provision by ESCOs and final consumers is presented in [20]. The research also analyzes the conditions for a more active role of consumers served by such technologies (i.e. setting their energy consumption in advance) through ESCO approaches. Moreover, the development of novel concepts such as *smart grid, multi-energy virtual power plant* and *smart city* also opens new business opportunities and market roles for ESCOs, that could include in their portfolio ancillary energy services such as energy storage, dispatchable loads, active demand side management. The ESCO could thus operate both in retail markets, attempting to avoid transmission and distribution-related grid charges by trading directly within the physical threshold of a microgrid, and local service markets, which are smaller version of ancillary service markets established between DSO and potential sources of grid control power. In [21], various ESCO ownership models for smart grids are described, including establishment of 'prosumer' (producer–consumer) consortium that can be operated by an ESCO.

1.3. ESCO and bioenergy

Biomass energy can play a significant role in the achievement of the energy policy targets at EU level by 2020. In particular, the Italian National Action Plan poses a great emphasis on the contribution of biomass to future Italian energy mix [22], with a target of 5.6 MTOE of biomass energy by 2020 in comparison to 1.8 MToe of 2010, and a major contribution of biomass heating. High thermal conversion efficiency makes heat generation from biomass an optimal use of this limited resource, and this potential can be further maximized by on site CHP. In several cases, the scarce know-how and high upfront costs of biomass heating or CHP and DH projects are major barriers for the implementation of such projects by final end users, and an ESCO approach could facilitate them. There is a wide literature in the broad field of on site biomass heating and CHP, including topics such as: (i) reviews and design of on site conversion technologies [22–28], (ii) decoupling of biomass processing and final energy conversion systems [29,30], (iii) supply chain optimization models [31–36], (iv) district heating and cooling design and optimization [35–41], (v) planning and optimal sizing of biomass distributed generation [42–46], and micro CHP [47–49], (vi) operating strategies assessment [50–52], and (vii) technical, economic, environmental and social performances assessment of a number of small scale bioenergy options [53–60,122]. However, there is by far less literature in the specific field of biomass-ESCO approaches and business models. A techno-economic assessment of the feasibility of biomass CHP systems for community housing and operated within an ESCO supply scenario is reported in [61]. The results show that, within realistic ESCO operating scenarios, biomass CHP can demonstrate positive economic performances without the need for capital subsidies, while end-users could benefit of discounted energy tariffs compared to mainstream utility companies. The best performances are found for high load factors when both heat and electricity sales are maximized. Various business models of small-scale wood heat generation in Finland are presented in [62], including public–private partnerships, cooperatives and ESCO business models.

1.4. Aims and scope

This paper aims at assessing the business models, key factors and economic profitability of ESCO approaches for the implementation of biomass heating and CHP in Italy by means of representative case studies. The paper partially draws upon work done within the EIE BioSolESCO project (EIE-07-264, 2008–2011)– Expanding biomass and solar heating in public and private buildings via the energy services approach [63], which aimed at understanding the conditions for facilitating ESCO's approach for biomass and solar heat market expansion in the EU. The project implied a review and analysis of the solar/biomass ESCOs across EU member states, their specific regulatory, legal and financial frameworks, and the identification of the major issues and barriers for their implementation by learning from state-of-the-art exemplar energy service implementation in member countries.

The paper first introduces the ESCO approach and a framework to classify biomass-ESCOs business models and energy service contracts. In the following, the policy measures and legislative framework available to facilitate these market approaches in Italy are reviewed, and the state of the art of Italian biomass-ESCO market is reported. In the third part, some representative biomass-ESCO case studies are presented and the baseline input techno-economic parameters are introduced. The three different market segments under investigation are the agro-industrial, the tertiary and residential (district heating, DH) sectors. In the last section, the results of the financial appraisals of the investments and the key factors influencing the success of the biomass-ESCO approach

under the proposed scenarios are discussed. The results contribute to: (i) selecting end-user segments and particular conditions where the ESCO approach to the biomass heating and CHP service could be more promising, (ii) selecting the optimal business model for each market segment, (ii) defining the main technical and non technical barriers towards the biomass ESCO business in Italy; (iii) proposing policy measures to overcome these bottlenecks and facilitate the diffusion of biomass heating contracts.

2. ESCOs and biomass-ESCOs business models and barriers

2.1. ESCO business models

In its purest form, a business model can be defined as the description of a business including the elements of value proposition (how products and services generate value for the customer or stakeholders), configuration of value creation (definitions of core parts of the value chain) and revenue model (how the business generates revenues). As described in [61], 'a business model describes the architecture of the firm and its network of partners for creating, marketing and delivering value and relationship capital in order to generate revenues'. In this context, an ESCO business model can be defined as a model of the business architecture for energy services flows. The organizational structure and business model of ESCOs can be placed into various categories, on the basis of criteria such as organization of the products/fuels supply chains, ownerships, decision rights and responsibilities between all stakeholders involved, scope of supply, strategies to generate income and billing options. For example, the infrastructure and assets can be owned by the local authority, while the operation and management is done by the ESCO. The ownership and control of a scheme can be split in any number of ways between private management, public organization, cooperative of end-users, and external private equity. The details of each model are outside the scope of this work but can be reviewed in the relevant literature [38,64–67]. As an example, in [16,17], Sorrell classifies the energy service contracting of an ESCO operation on the basis of three main variables (scope, depth and method of finance), examining how these factors affect client's choices, ESCO financial risks and business profitability.

In the following, a classification of biomass-ESCO operations and typologies of contractual relationships is proposed, with a specific focus on the aspects that differentiate a biomass ESCO operation from a typical heat or CHP supply service.

2.2. Classifying biomass-ESCO operations and energy service contracts

In Fig. 1, the different steps of biomass-ESCO operations for heat or CHP are summarized, with a general framework of the possible business models and contractual relationships. Within this scheme, the peculiarities of biomass-ESCO operations regard mainly the biomass supply chain organization and the management of biomass conversion steps, while other aspects can be considered common to more traditional ESCO operations.

2.2.1. Biomass supply

The main options for biomass supply chain organization are:

- *ESCO vertically integrated*; ESCO is in charge of biomass production, harvesting, transport; the storage and conditioning can be carried out at the premises of the energy conversion plant or by means of intermediate biomass storage/upgrading facilities (decoupling processing and energy conversion steps [68]); the latter option is particularly suitable in case of: (i) several distributed conversion plants served by a centralized biomass processing facility; (ii) transport/storage/odours/air emissions and other amenity constraints at the premises of conversion plants near to heat loads.
- *Partial integration* of the biomass supply chain into ESCO business; the stages included in ESCO responsibilities can be the biomass transport, storage (to secure the supply of seasonal biomasses) or upgrading (drying, pelletization, torrefaction, pyrolysis to bio-oil, to increase the biofuel quality for high efficiency energy conversion processes [70]); some of these stages can be managed as subcontracts.
- *Third part biomass supply*; in this case the ESCO is only in charge of on site biomass storage to secure the plant operation, and purchases the biofuel on the market or by specific contracts with suppliers.
- *Biomass owned by the energy end-user*; it is the case of wood processing or agro-industrial firms that own by-products from the production process, Municipalities that collect organic fraction of urban wastes, Local Authorities that own forestry biomass.

In the latter cases, the biomass suppliers could also withdraw the amount of heat/power generated on the basis of an assumed plant conversion performance, according to 'tolling agreements' [71].

2.2.2. Ownership and financing

The investments determine much of the responsibilities regarding the practical operations and ownership of plants, networks and equipment. The ownership of an ESCO operation can be placed into the following categories:

- Working capital or debt provided by the ESCO, that owns and controls the plant and network, taking the whole financial risk; the end-user pays for energy consumed, commonly under an Energy Supply Contract with the ESCO, and can be in charge of specific equipment (i.e. civil works, heat exchangers); in some cases, the end-user receives ownership of the plant and equipment from the ESCO after the payback time of the investment (Build Own Operate Transfer contract, BOOT) [38];
- Working capital or debt provided by end-user that owns the plant and network, which is operated by the ESCO; in some cases, no-profit or community/end-users cooperatives may have the ownership; in these scenarios, the customer has higher level of decision rights and control over the service, and the ESCO guarantees the performances;
- Partnership ESCO-end-user/cooperative; the ESCO and the end-user can share the investment risk; this increases the proportion of energy cost savings allocated to the end-user, in the form of reduced billing charge, and facilitates the operation in particular for small ESCOs, decreasing their debt/equity ratio;
- Public sector organization, public utility or a third operator provides working capital or debt, has the ownership and sales energy to end-users; the ESCO operates the plant according to the energy service contract, providing performance guarantees to the investor;
- Partnership ESCO-public organization; in this case the public organization can be in charge of part of the investment, receiving the investment money back by a share of the capacity billing charge (or energy cost savings in case of public end-users). This scenario can be dominant in case of high investment costs for energy infrastructures (DH networks, customer connection to pipelines), where municipalities can not only be in charge of these investments, but also: (i) facilitate permitting issues and expropriation procedures, (ii) connect public buildings, (iii) guide and incentivize end-users to connect to the network, (iv) introduce new planning agreements, long term

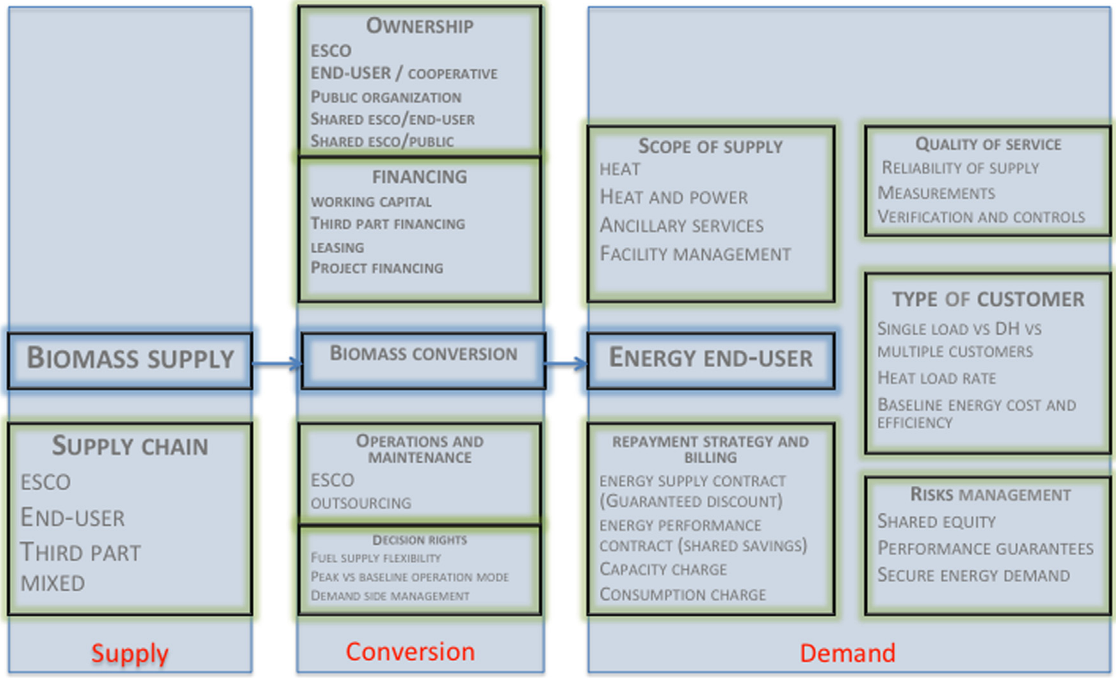

Fig. 1. Flowchart of biomass-ESCO operation stages reporting typologies of business models and contractual relationships.

heat strategies and urban areas development plans for DH networks.

The appropriate choice depends upon the context, including the amount of investment, familiarity of lenders with financing different types of project, the credit status of energy service providers and end-users, public sector procurement rules and the accounting rules for tax and depreciation.

Public company financing has proved particularly attractive in the US public sector, where public end-users qualify for tax-exempt loans. The same is not true in Europe, where government procurement, accounting and budgeting rules have led many public sector organizations to seek off-balance sheet financing [69]. This difference explains the differing size and focus of the US and European energy service markets [17].

2.2.3. O&M, depth of supply and decision rights

The plant operation is commonly under the control of the ESCO, which is responsible for the reliability of the conversion process, having the specific know-how. However, ESCO can outsource some steps of the process, (i.e. quality check on the biomass, ashes discharge, supply of fuels for back-up boilers). The outsourcing is related to the concept of 'contract depth' [17], defined as the amount of organizational activities required for the provision of the energy service that is under the control of the ESCO. Increasing contract depth increases the control the contractor has over the cost of producing the final services. This implies a threshold for contract depth below which a contractor is unable to offer an energy service contract owing to insufficient control over equipment cost, operation and performance. Generally, the more control the ESCO has, the less risk it assumes. In this dimension, another relevant aspect is the allocation of operational decision rights between ESCO and end-user, strictly connected to other dimensions (i.e. ownership, scope of supply, quality of service, repayment strategy). In particular, the ESCO can have decision rights on CHP plant operation mode (heat/electricity driven or baseload, if the selected biomass technology allows operational flexibility), fuel supply (i.e. selecting dual fuel operating options), maintenance scheduling, or investment strategies for refurbishment of plants and infrastructures. Further operational strategies such as heat storage, local energy balance and the provision of demand side management services (i.e. load shaving/shifting options, interruptible loads management) can also be classified under the umbrella of such dimension.

2.2.4. Scope of supply

The scope of an energy service contract may be defined as the amount of energy streams and/or final energy services that are wholly or partially under the control of the ESCO. At one extreme, a contract could include a single energy service or energy stream (i.e. only plant operation and maintenance, or sale of biomass heating), while at the other extreme it could include all the final energy services and energy streams, such as total heat and power demand of the end-user (chauffage contracts), including cooling service (by biomass-fired adsorption chillers), provision of demand side management and ancillary services [21], refurbishment/repowering of existing energy infrastructures. In the case of biomass ESCO, this means that heat from natural gas fired back up boilers or electricity purchased on the wholesale market can be used to match the customer energy demand, in addition to the bio-energy generated. Moreover, in the case of biomass CHP, the electricity can be on site consumed by the end-user or fed into the grid, on the basis of the relative values of the bio-electricity feed-in tariff and selling price of electricity to the customer.

The provision of further energy efficiency measures on buildings and/or electrical and thermal equipment in the ownership of the end-user is strictly related to the implementation of Energy Performance Contracting, as discussed in the following section. However, efficiency measures in buildings are difficult to be implemented by biomass-ESCOs providing heat services, because of the upfront capital required, the difficulties in defining ownership and measuring the related energy savings, and the specific know how needed. Moreover, as discussed in the 'ownership and financing' section, some energy services and related investments can be out of the ESCO scope of supply, such as expensive DH networks and final customer's heat networks connection costs. In this case, the heat can be delivered

to a heat distribution operator (public company) in charge of the final distribution to the end-users.

Generally, the greater the scope of the contract, the more control the contractor has over the overall energy system. In the extreme, all the energy systems and services for the entire site may be outsourced. Moreover, it is increasingly common for supply contracts to extend beyond energy to include services such as water treatment, water supply and wastewater disposal, together with the supply of industrial gases; they could also extend into wider facilities management activities such as telecommunications, security and grounds maintenance.

2.2.5. Repayment strategy and billing system

The repayment strategy of a biomass-ESCO is generally based on “guaranteed performances” and “shared savings”, on the basis of the ownership of the investments [3]. In the ‘guaranteed’ mechanism, the ESCO guarantees a certain level of plant performances sufficient to cover clients' annual debt obligation, and protects the client from any performance risk. The client repays the loan and the credit risk stays with the lender [4]. In the “shared” mechanism, ESCO carries both the performance and the credit risk. ESCO repays the loan and the credit risk stays with the ESCO; the client assumes no financial risk and takes a shared quota of earnings from the ESCO operation. The client assumes no financial obligation other than to pay to the ESCO a percentage of the actual savings or the energy consumed, over a specified period of time [2,4]. Mixed financing mechanisms also are possible, such as “guaranteed” schemes with credit risk shared between ESCO and client, including “performance incentives” to the ESCO if specific targets are achieved.

However, within the “shared savings” mechanism, two major repayment strategies related to the energy sales of an ESCO can be implemented: energy supply contracting (ESC) and energy performance contracting (EPC). ESC is the most common contract in case of biomass-ESCOs, and it is implemented through a guaranteed discount the ESCO offers to the baseline unitary energy cost of the end-user. In this case, there is less motivation for the ESCO to improve demand side energy efficiency, since it is receiving an income for the sold energy, independently of the reduction of energy consumption (the higher is the end-user energy demand, the higher is the profitability for the ESCO). These contracts generally operate on a low-margin, low-risk basis, with business models often focused on securing long-term operation, supply and/or maintenance contracts. On the contrary, EPC enables investment in energy efficiency, since the costs saved through the reduction of end-user energy demand by the installation of efficiency measures are shared between the ESCO, the end-user and the further operators involved (i.e. public companies) [38]. Other forms of contracts that can incentive demand side energy efficiency, despite not properly under the umbrella of energy service contracts as defined by legislation [77], are the “heating degree-day” contract (discussed in the ‘measurement’ section), or the fixed ‘forfeit’ charge, calculated on the basis of average end-user consumption of previous years.

As regards billing strategies, the ‘capacity and usage charge’ includes a fixed capacity-based charge and a variable charge based on the energy consumed. It is the most common billing contract in case of DH or when high investment costs must be repaid by the ESCO. On the contrary, when the energy is delivered to large single end-users, a consumption-based charge is commonly used. In order to minimize the risks of energy demand variations, thus securing the repayment of investment costs, billing schemes with high fixed capacity charge can be applied.

2.2.6. Type of end-users

The biomass ESCO operation is highly influenced by the typology of end-user. A detailed market segmentation of potential bioenergy demand in the residential sector has been proposed in [72], while a possible segmentation of the whole potential heat demand to be served by ESCO operations is based on the following criteria:

- size and number of customers: single load vs multiple customers served by district heating infrastructure; in the case of several end-users, customer transaction and inertia costs can be major barriers, and a public-private partnership can facilitate the operation [38,65,67];
- typology of heat demand: high heat load rates and high temperature levels are typical of process heat for agro-industrial or industrial applications, while low heat rates are typical of residential energy demand and warm latitudes; this is one of the key factors addressed in the next section;
- baseline energy cost and energy efficiency levels: in most cases, residential sector presents higher energy costs than tertiary and industrial ones (where lower tax rates and wholesale market purchases of fuels may reduce costs); moreover, the presence of natural gas supply and/or new and efficient energy infrastructures and equipment available at the customer premises are other key factors that can influence the profitability of biomass ESCO operations;
- typology of energy service (only heat, CHP, CCHP); this highly influences the upfront capital required, since CHP options can strongly increase both the ESCO pay back time and, in some favorable policy frameworks, the profitability of the projects, in comparison to only heat generation; moreover, in particular in the residential and tertiary sectors, the options of trigeneration or heating/cooling services by adsorption chillers can improve the environmental performance and economic profitability of the investments [23,43,73];
- private vs public end-user: in the latter case, public procurement procedures are commonly required.

2.2.7. Measurements and quality of service

The quality of energy services and the measurement and verification systems are other important aspects of ESCO operations. In particular, the implementation of customer satisfaction systems, fast and reliable maintenance services, measurement and control of temperatures to guarantee comfort levels and high performances are aspects that can be included in the energy service contract. The energy sales can be quantified by means of fuel consumption of the plant or measurement of energy delivered to the end-user (hence excluding energy losses of heat distribution networks and plant generation); the latter option motivates the ESCO to maintain high energy performance levels *before* the point of measurement (but not necessarily also *after* it). In case of variable heat demand patterns and for large consumers (public and tertiary sectors), the energy contracts and billing strategies are often based on “heating degree-day” metering systems. In this case, the consumption-based charge is calculated on the basis of the daily mean temperature, thus incorporating only the weather risk and not the consumer behaviour risk when forecasting the energy demand and future revenues. Moreover, these contracts can motivate the ESCO to implement energy efficiency measures to decrease the end-user energy consumption, being the repayment based only on weather conditions and not energy delivered.

2.2.8. Risks allocation

There are several risk management strategies for ESCO operations, which can be classified according to the following:

- *supply-side*: securing the biomass supply by long term contracts, selection of reliable suppliers and mixed ownership with

biomass producers, in order to avoid scarcity of supply, uncertain quality and volatile prices;

- *technology*: reducing the technological risks in case of outsourcing of specific services, that present high know-how requirements and low technical maturity and reliability, through shared ownership (and equity) with subcontractors and specific performance guarantees;
- *demand-side*: securing the energy demand by means of minimum energy consumption levels or billing strategies with fixed capacity-charge; indexing energy prices on the basis of biofuel supply costs.

2.3. Barriers towards biomass-ESCO approaches at EU level

As highlighted by previous contributions [4,5], major differences exist in the development of ESCOs business among various European countries. This also applies to the specific biomass markets and ESCOs operating in it. A review of biomass heat ESCO's markets status in the EU-27 countries, with a particular focus on regulatory, financial and contractual frameworks was carried out within the BioSolESCO project, with the aim of identifying the major non-technical barriers for ESCOs operations in the biomass (and solar) heating sectors [63]. The results show that European biomass heat ESCOs markets are not homogeneous and present remarkable differences among member countries both in terms of national market development and technologies used (e.g. Central and North European countries are generally more experienced in biomass heating systems) and in terms of regulatory and contractual framework [74]. For example, the type of contract used ranges from EPC and TPF to more country specific schemes such as heat supply contracts and chauffage contracts [75]. The form of financing varies as well including forms of ESCO's financing, TPF or end user/customer financing.

The review of ESCOs markets also revealed the existence of several major non-technical barriers to the successful implementation of ESCO approach for biomass heating [75,76]. The main factors can be summarized as follows:

- the most relevant regulatory barrier is the length and complexity of public procurement procedures, which hinders the development of otherwise highly profitable investments in the public sector (with a typical presence of high energy demand of end users that can also act as anchor loads, e.g. hospitals, leisure and sport centers, etc.);
- access to credit is a relevant issue for ESCOs, in particular in countries where this approach is not widespread and financial institution are less familiar with the procedures associated with an ESCO operation or the business is perceived too risky and scarcely profitable; quite often high guarantees and/or high equity share is required thus allowing only the biggest players to enter the market;
- the lack of standardized contracts arrangements complicates transactions as well as the assessment of the investment from credit institution, limiting the ability of the ESCO to raise capital and increasing the cost of capital itself;
- low awareness and poor understanding of technologies and their implementation, both from the end users and financial institutions, is still a barrier for successful development of an ESCO approach in most biomass heat markets across Europe.

Through the analysis of exemplar biomass ESCO operations, the BioSolESCO project has also explored very practical implementation issues faced by ESCOs across Europe. The learned lessons can be summarized as follow: (i) energy agencies providing expertise and assistance to municipalities in implementing energy contracting projects are crucial for increasing the uptake of contracting schemes; (ii) a well organized contracting business sector is required to provide information and advices, to do lobbying in order to adapt laws, standardize definitions and procedures; (iii) the establishment of a clear legislative framework capable to regulate all the energy contract details is crucial since uncertainties resulting from unclear legal status are a major barrier; (iv) contractors offering the whole array of technologies and fuels can provide the most efficient concept depending on the project situation; (v) contracting is often not applicable in smaller projects with low investments, and the pooling of customers is an appropriate tool to increase project volumes; (vi) standardized measurement and verification procedures are necessary; (vii) project risk forecast and clear risk analysis are necessary; (viii) there is a need for increasing public awareness about ESCO projects and their technical and financial viability. The review of EU and non-EU ESCOs' development proposed in [18] confirmed that the main barriers are the legal/political and the social/cultural ones. These barriers can be due to weaknesses in the provision of effective political support, absence of the verification protocols for the certification of the contract's guarantees, reduced interest for ESCOs and scarcity of educational policy on energy savings.

In conclusion, along with transparent regulatory frameworks and standardized contracting procedures, the need for clear information and understanding of technical and financial viability of ESCOs operation is still of outmost importance. Such information would be of help in reducing (perceived) risks associated to such type of investments. The next section will thus focus on further exploring the case for investments in biomass technologies using an ESCO approach in the specific Italian energy system context. The financial viability of biomass heating and CHP investments for three different market segments is assessed. This allow exploring under which conditions and for which possible applications/market segments the ESCO approach could be more appropriate and less likely to incur in some of the non-technical barriers discussed above.

3. Overview of ESCOs in Italy

3.1. Legislative framework for biomass ESCOs

In order to explore the case for investments in biomass technologies of the next section, and to assess the main non-technical barriers towards ESCO developments in Italy, an overview of national legislative framework related to energy service contracts, energy efficiency and on site/renewable energy is proposed in the following.

- ESCO approaches and energy service contracts
  The *Dlg 412/93*, which defined the technical rules for thermal energy plants design and operations, including standards for energy efficiency and rationale use of energy, firstly introduced the '*heat service*' concept. However, only the *Dlg 115/08* [77] (transposition of the European Directive 2006/32/CE related to end-user energy efficiency and energy services) introduced a clear framework for energy service contracts, ESCO operation, energy performance contracting and energy efficiency in Italy. It also introduced monitoring standards to achieve energy efficiency targets, simplified permitting procedures to facilitate the energy services approach and remove administrative barriers, facilitation of third-party financing, procedures for qualification and certification for ESCOs and for energy consumption metering and billing.
  The liberalization of electricity (*Dlg 79/99*) and gas (*Dlg 164/00*) sectors also contributed to an increased competitiveness of the Italian energy market thus facilitating ESCO approaches.

- Energy efficiency
  The Ministry Decrees of 20/7/04 on energy efficiency introduced a market-based system (also known as White Certificates mechanism, WhC) for the promotion of energy efficiency measures for end-users. It is based on a mandatory quota of primary energy savings to be achieved by electricity and natural gas grid distribution operators (GDOs), by means of end-users energy efficiency measures (that include the use of biomass heating and CHP systems). One WhC is issued for each TOE of primary energy saved, and is traded on a dedicated market, participated by ESCOs and GDOs [78,79]. Furthermore, *Law 244/07* and *Law 185/08* introduced some important actions to promote end-user energy efficiency, and in particular a tax allowance of 55% of the full costs of energy efficiency measures implemented into existing buildings (including biomass boilers owned by end-users). As regards residential sector and buildings, the *Dlg 192/05* (transposition of European Directive 91/2002 related to energy performance in buildings) and successively the *Dlg 311/06* introduced standards for energy efficiency and renewable energy in buildings, with mandatory energy labelling for new and refurbished buildings, and compulsory use of renewable energy for public buildings;
- Distributed generation, CHP and DH
  The *Dlg 20/07* introduced comprehensive measures to promote CHP and on site generation, including the net-metering option for the so-called '*high efficiency*' CHP plants (those ones which respect specific 'primary energy saving' and 'useful heat' standards as defined by the Ministry Decree 04/08/11) having size up to 200 kWe; the Ministry Decree of 10/09/11 introduced specific incentives for 'high-efficiency' CHP in the form of WhC issued for the primary energy saved by these plants. Specific measures to promote district heating were introduced by the *Law 388/00* (art. 29), through a tax exemption of 20.66 Eur/kW for end-users connected to a DH network, and by the *Law 203/09* (art 2), through a tax exemption of 25.80 Eur/MW h for end-users connected to a DH network fed by biomass plants (only for climatic areas E and F);
- Biomass energy
  The *Dlg 28/11* [80] and the successive Ministry Decree of 06/07/12 [81] reformed the subsidy framework for renewable electricity (including biomass) established by the *Dlg 387/03*. A feed-in tariff mechanism was introduced, differentiated on the basis of plant size, technology and biomass sources, including specific bonus for low air emission levels, use of heat, district heating and sustainable supply chains. In case of plant size above 5 MWe, a bidding support system was also introduced (substituting the existing '*green certificates*' system). The same Decree also introduced several measures to facilitate the penetration of renewable and biomass heating, such as: (i) mandatory use of renewables in new buildings or in case of refurbishment, and simplified permitting procedures for renewable heating (art 11); (ii) feed in tariff for small scale renewable thermal energy, and in particular for biomass heating (art 28); (iii) revision of white certificates mechanism, with an extended duration for energy efficiency measures having lifetime higher than the 5 years (art 29); (iv) incentives for bio-methane fed into gas network, that could be used for heating or cogeneration near to the energy demand (art 21); in this case, the bio-fuel can be produced at the premises of biomass resources and transported to the loads by existing gas networks, so mobilizing new ESCO schemes and investments in biomass heating and integration into existing energy systems, such as combined use of bio-methane and natural gas into domestic boilers of centralized CHP systems—however, this measure still has to be put into practice; (v) special funds for new district heating networks, with simplifications of related permitting issues, and for industrial investments in energy efficiency measures coupled to major refurbishments (art 22 and 32). Moreover, the *Dlg 387/03* and successive Ministry Decree 10/09/10 introduced guidelines and standards to regulate and fasten the permitting procedures for renewable energy systems (which represents one of the main barriers for their development in Italy, and are very jeopardized at regional and local level) facilitating on site generation and cogeneration plants. Finally, the *Dlg152/06* defines air emission limits and monitoring systems for biomass conversion plants, including standards for biofuels, ashes discharge procedures, soil and water environmental impacts.

The Italian legislative framework, even if characterized by the innovative WhC market mechanism and generous feed-in tariffs for renewable energy, presents several crucial issues to be addressed, namely the poor reliability of policy measures, the high delays in putting into practice the general energy policy strategies, the high complexity of permitting and administrative procedures (which are not simplified by specific legislation as expected), the lack of effective support systems for renewable heat. In the field of public procurement, administrations face the problem of establishing fair and effective criteria in the tendering for energy service contracts, while the absence of a clear regulation and a general lack of knowledge or misperception of the renewable thermal technology have discouraged so far public administrations in undertaking investments in renewable heat.

3.2. ESCO and biomass-ESCO market in Italy

The Italian ESCO's market is characterized by a large number of companies and business models. The first ESCo started to operate in Italy in the early 80's by providing 'heat service' to public buildings. In 1984, the association of heat supply companies (ASSOCALOR) was established, substituted by AGESI (the Italian energy service industry association) in the middle of 90's. Currently, most of the ESCOs are SME, and about 70% has less than 15 employees, with average turnover below 2.5 M€/year for 80% of them [82]. The customers are mainly Public Administrations (21%), Small and Medium enterprises (21%) and industrial sector (19%), despite the civil sector (both tertiary and residential) presents the highest growth rate. Less than 50% of the Italian ESCOs implemented projects dealing with renewable energy. Most of the ESCO applications are related to electricity (both end-use efficiency and generation), and the most profitable area of ESCOs business regards electric components (in particular repowering of electric engines and lighting, in the public and private sectors). As regards heat energy services, the main market segments are large users (mostly public administration and hospitals), where the refurbishment of thermal plants and the installation of CHP plants are the most implemented actions.

The main Italian ESCOs involved in the heat service for large consumers (hospitals, public sector, aggregate of residential consumers and also industrial consumers) are Cofely, Siram, Fenice, Manutencoop, ABB, CPL Concordia. These companies often offer a global energy service, including CHP. They are characterized by high know-how, high credit rate for access to financing, and economies of scale. Recently, Property Management, Real Estate and Facility Management Companies are also approaching the same market, enforced by their strong financial capacities, customers portfolio and management skills. The umbrella of services includes energy management (heating, cooling, lighting services), facility management (cleaning, reception, security, representative services) and property management (rent, O&M and building management). Other operators are energy utilities and electricity distributors, in most cases with a strong presence on the territory, such as Hera Group (Emilia Romagna Region), Acea (Rome Municipality),

Ageas (Campania Region), SEA (Valle d'Aosta Region), A2A and ASM Brescia (Lombardia Region). In some cases, these operators own urban district heating systems or electricity networks, in others they are in charge of ESCO operations at the premises of industrial firms. The main activities of these companies are based upon CHP and district heating projects, and they can develop from 1 up to 3 projects per year with a medium rate of investment of 0.1 up to 2 MEuro and a medium installed power of 0.5–2 MW.

Another category of biomass ESCos is represented by manufacturers of biomass boilers (i.e. Riello, Uniconfort), registered as ESCos in order to trade the WhC generated by the installation of their products. These companies can participate to the energy investments with part of the equity (in the form of supply of components and works) and take part of the risk by guaranteed performance contracts. Moreover, there is a number of other SME operating like ESCO, able to propose a wide range of energy services and energy efficiency investments. These companies have average turnover of 1–10 MEur/year, and in most cases are out of the biggest public procurements. Emerging ESCOs include engineering companies, focused on energy audits and on energy saving measures. They follow the project from the audit stage to engineering and construction, using outsourcing to fill out the work. As regards the biomass heating service, most of the biomass ESCOs are located in North Italy, where about 550 MWt of district heating plants and 735 km of district heating pipeline have been installed since 2008, with thermal and electric power generation respectively of 585 and 48.75 GW/yr [83].

3.3. Barriers for biomass ESCO penetration in Italy

The main barriers for biomass ESCO business in Italy regard policy, administrative, financial and market issues, and are in most cases common to other EU countries [74]. The main technical barriers are: (i) technology reliability (mostly for small scale CHP plants); (ii) air emission levels and ashes discharge (mainly in small and residential applications); (iii) limited know-how about installation, plants dimensioning and integration into existing customer's facilities; (iv) storage, logistic and biomass supply and handling issues (mainly in urban areas and where space is a constraint); (v) heating measurement systems (in particular where several end-users are served). However, the main barrier towards the development of ESCO schemes is given by supporting measures unreliability (confirmed by the delay in the introduction of the feed-in tariff for renewable heating established by Dlg 28/11). Permitting issues and complex public procurement rules are further constraints in the public sector segment. Financing issues are highly relevant, in particular in case of small ESCO and start-up companies with limited credit scores. Specific financial products should be available for biomass plants, in order to cover the annual biomass supply costs and possible mismatches with energy sales revenues. Moreover, the biofuel supply and related price should be secured with proper contracts, in particular if the ESCO is not vertically integrated to the biomass production chain. Some other biomass-specific barriers regard the biomass markets reliability and quality standards, the social acceptability, the tax regimes (VAT on wood chips is set at 20% instead of 10% as in EU's countries, so hindering the trade and limiting a fair competition [84]).

4. The selected biomass ESCO operations

4.1. Case studies and business models

The ESCO approach for biomass heating is tested for three market segments within Italian energy market: the agro industrial (case study 1, dairy firm), tertiary (case study 2, hospital) and residential (case study 3, borough district heating) sectors. A financial appraisal of investments in biomass heating within these market segments is done through discounted cash flow analysis and calculation of the economic indices net present value (NPV), internal rate of return (IRR) and profitability index (PI). The aim is to evaluate the profitability of the investment as well as to explore the key factors affecting it. Two alternatives for the use of the biomass plant are explored: (a) only heat generation; (b) cogeneration of heat and power (CHP). This leads to six different scenarios, two for each case study. For all scenarios, a wood chips fired thermal plant of about 6 MWt (nominal output power) is assumed. In case studies 2 and 3, a natural gas fired back up boiler is also included in order to increase the overall installed thermal power and match the end-user heat demand. The main techno-economic assumptions for the proposed ESCO operations are reported in Annex I, while the main parameters and business models for each case study are reported in Tables 1 and 2. The duration of ESCO operation represents the number of years of ESCO ownership and sale of energy to the customer, under a BOOT contract. In the case of CHP, the high investment costs require a longer duration of ESCO operation, equal to the duration of electricity feed-in tariff and to the lifetime of the project (20 years).

4.2. Biomass supply

The focus is on solid wood fuel in the form of woodchips, which can be produced from sources such as agricultural pruning residues, clean industrial and commercial wood waste, urban tree waste and forestry residues. However, where such biomass waste streams are utilized, consideration should be given to factors such as legislative constraints on usage, environmental impact and potential impacts of poor fuel quality on equipment operation and control. The biomass and fossil fuels costs and quality are reported in Annex I. Literature data about wood chips supply costs in the Italian market report a price range of 30–80 Eur/t, according to its quality, geographical area, period of the year, typology of biomass supply chain and number of operators involved [85,86]. In this study, a cost of 70 Eur/t (including transport to the plant) is assumed. This cost could be 50–70% lower in case of vertically integrated business models, where the ESCO is also in charge of biomass supply.

4.3. Energy demand and heat distribution system

The *heat load rate* is one of the most important factors when assessing the feasibility of ESCO approaches for biomass heating. In the agro-industrial case study, a very high heat load rate is assumed, according to thermal energy consumption data collected from the dairy firm under investigation [87–89]. In the tertiary sector case study, the heat load rate is assumed on the basis of typical data from literature [90–95] and considering hospital size of 800 beds with thermal energy consumption of 22 MW h/yr per bed. In the residential sector case study, the heat load rate is correspondent to a climatic area E, with a total heated area of about 115,000 m^2 dwellings, 2800 inhabitants served and specific thermal energy consumption for dwellings of 0.07 kW/m^2 yr [96].

The investment in the *heat distribution system* is another key factor, in particular in case of large district heating networks. In fact, the high district heating costs, the heat transport losses and the construction permitting issues, that can be particularly complex in urban areas, require a location of the power plant at the premises of thermal energy customers, and in areas with high linear thermal density (above 1.5–2 MW h/yr km) [97–100]. In the case study 1, no heat distribution costs are considered, since the biomass plant is located at the premises of the dairy firm. In the case study 2, the length of the heat distribution network is assumed 800 m, while the further heat distribution costs within

Table 1
Summary and main parameters of selected biomass-ESCO operations.

	1-a	1-b	2-a	2-b	3-a	3-b
Market segment	Agro-industrial (diary firm)		Tertiary (hospital)		Residential (borough)	
Investment cost for ESCO (kEur)	816	4,623	1,294	5,103	3,351	7,785
Duration of ESCO operation (yr)	5	20	5	20	10	20
O&M costs (kEur/yr) [a]	1,110	1,647	555	1,407	442	1,329
- of which Biomass supply cost (kEur/yr)	1,081	1,323	419	974	301	910
Baseline condition	Existing energy equipment owned by end-user (baseline efficiency in Annex I)					
Baseline heating cost (Eur/MW h) [b]	41.7		58.9		98.3	
Heat load rate (%)[c]	80%	80%	25%	25%	18%	18%

[a] Details reported in Annex I, unitary biomass cost 70 Eur/t.
[b] Details reported in Annex I.
[c] Represents the equivalent annual plant operation at nominal power, and is dependent on the typology of heat demand.

Table 2
Summary of business models for the proposed biomass ESCO operations.

	1-a	1-b	2-a	2-b	3-a	3-b
Biomass supply	Third part supply with on site storage in charge of the ESCO					
Scope of contract	Total heat demand of load (CHP electricity fed into the grid and feed-in tariff available)					
Ownership [a]	ESCO—customer after first 5 years (BOOT contract)	ESCO	ESCO—customer after first 5 years (BOOT contract)	ESCO	ESCO—customer after first 10 years (BOOT contract)	ESCO
Repayment strategy	Shared savings: Energy Supply Contract with discount on baseline energy costs					
Billing	Consumption based charge					
Outsourcing	Not considered (all services provided by the ESCO)					
Metering	Measurement of energy delivered to the load					

[a] Upfront capital provided by the ESCO; customer in charge of civil works for plant construction (case 1 and 2, respectively 50 and 100 kEur) and heat exchanger costs (570 kEur for case study 3).

the hospital are assumed in charge of the end-user. In the case 3 (district heating for blocks of buildings) a linear thermal density of 1.9 MW h/yr km is assumed, corresponding to a district heating length of 0.8 m/kW and a total length of 6.5 km.

4.4. Energy selling prices

The heating selling price is calculated applying a discount of 15% on the baseline thermal energy costs. The further income for ESCO resulting from the sale of WhC (available only in the case of heat generation) is calculated assuming unitary price of 70 Eur/Toe [78], and a multiplicative coefficient of 3.36 [104,105]. As regards the electricity selling price of the biomass CHP plant, a fixed feed-in tariff of 249 and 279 Eur/MW h is considered, respectively for the case 1 (only cogeneration) and case 2 and 3 (district heating) [81], constant over 20 years.

5. Results and discussion

5.1. Economic appraisals and sensitivity assessment

In Table 3 the economic indices for ESCO operations referred to the different case studies are reported. A sensitivity assessment of the main techno-economic factors that influence the profitability of the investment is also reported in Fig. 2.

As can be seen, case 1a is extremely profitable, because of the high baseline energy cost, the high load rate of the customer, the availability of WhC incentives for biomass heating during the first 5 years of plant operation. Case 1b is also very profitable, even if the higher investment cost determines a longer pay back time and lower IRR. Case 2a is also a profitable investment, because of the presence of a concentrated load with high heat load rate at medium-high baseline energy cost. Finally, case 3 is the least profitable investment, because of the high district heating cost and the lower heat load rate, that are not compensated by the higher thermal energy selling price for residential end-users. In all cases, the higher investment cost of a CHP configuration, even if attracting further income from the electricity feed-in tariff, does not present higher profitability than the only heat generation plant. In addition, the heat load rate results a more influencing factor than the thermal energy selling price (case 1 with the highest heat load rate but with lowest heat selling price is the more profitable case study).

Table 3
Economic indices for the case studies, calculated for the duration of the ESCO operation (as from Table 1) and for the whole lifetime of the project (20 years); in case of CHP (case study-b) the duration of ESCO operation is 20 years.

Case study	NPV	PI	IRR (%)	NPV-20 yr	PI-20 yr	IRR-20 yr (%)	PBT
1a	3944	5.83	152	5712	8.00	152	1
1b	5100	2.10	23				7
2a	1848	2.43	43	2747	3.12	44	3
2b	2980	1.58	17				10
3a	224	1.07	12	1749	1.52	18	9
3b	1581	1.20	13				15

The results of the sensitivity assessment are shown in Fig. 2. As can be seen, case study 1 remains profitable even varying the techno-economic parameters up to 40% respect to the reference values. In all case studies related to only heat generation, the most influencing factors are the heat load rate, the investment cost, the baseline fossil fuel costs and baseline conversion efficiencies (that influence the thermal energy selling price under the selected 'shared savings' ESCO approach). The selection of the optimal market segment is thus a key factor to guarantee the profitability of the ESCO operation. Moreover, with the assumed hypotheses, the profitability of the investment is guaranteed in case 2a even in the worst sensitivity scenarios. On the contrary, case 3a is not profitable when increasing investment costs, decreasing heat load rate or varying baseline energy costs and efficiencies of more than 20%. In case of CHP, the investment costs,

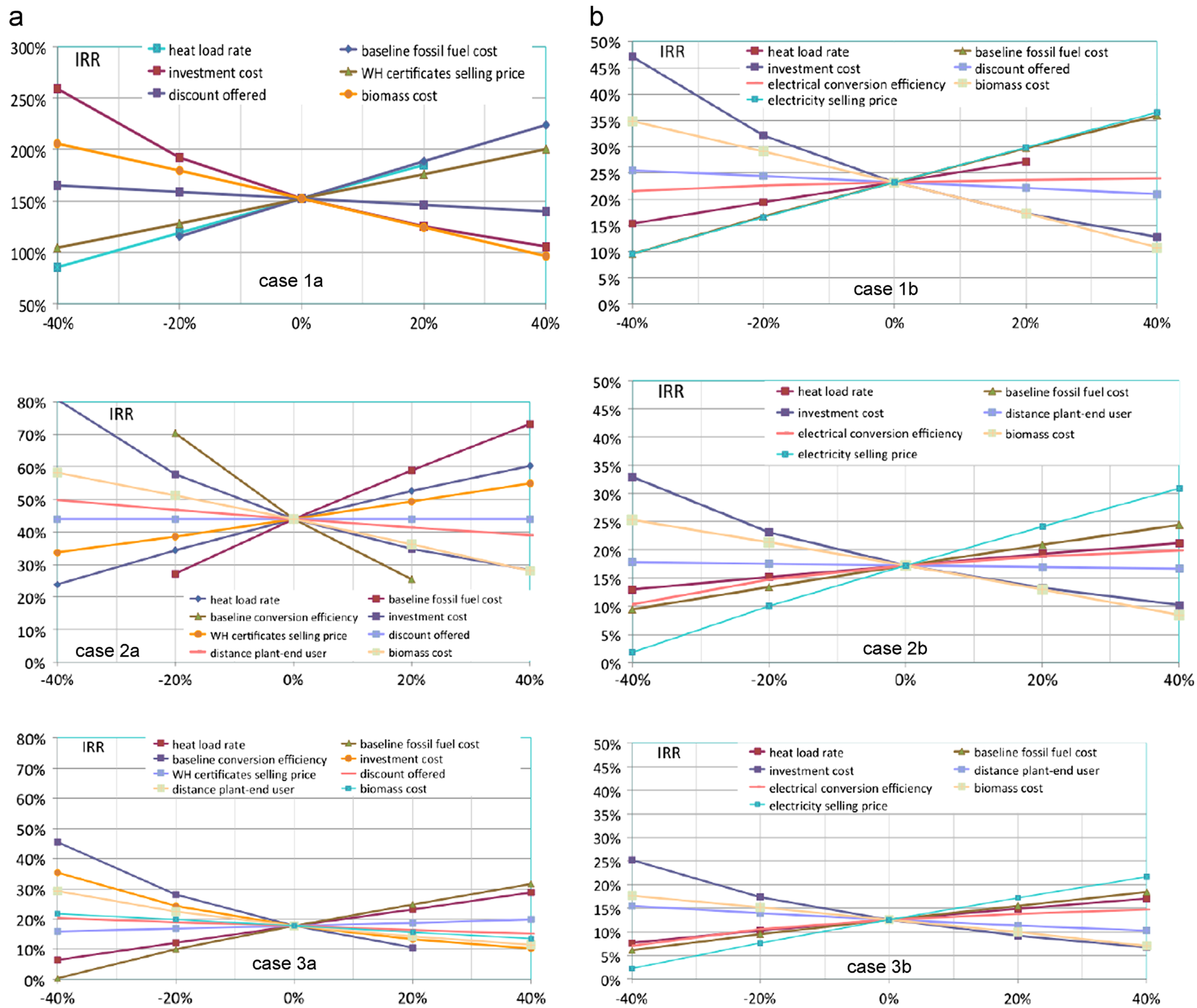

Fig. 2. Sensitivity assessment of the main techno-economic parameters of the proposed case studies, with cogeneration (b) and without cogeneration (a); (*y*-axis: IRR of the investment calculated over 20 years of plant lifetime; *y*-axis: percentage of variation of the parameter).

biomass supply costs and electricity selling price become the most influencing factors. Moreover, the sensitivity of IRR of CHP investments to the variation of the main techno-economic parameters is lower than in the case of only heat generation.

Further aspects that are relevant when selecting the market segments for the implementation of ESCO approaches, even if not captured in the profitability assessment, are: (i) the permitting issues, that are in general easier for industrial customers, and the related environmental concerns (in particular air emission levels of biomass boilers) that often hinder these applications in urban areas; (ii) the number of energy contracts and the related demand aggregation level, that makes more promising few large consumers (i.e. hospitals) instead of several residential end-users; (iii) the access to loans, that makes easier the development of biomass heating schemes instead of CHP ones.

5.2. Key factors and business models for biomass ESCO operations

Table 4 summarizes the main key factors influencing the feasibility of the proposed ESCO operations, classifying them as supply, demand and policy related factors. As regards the possible biomass ESCO business models, the most promising ones present a vertically integrated biomass supply chain, where the ESCO can secure and control the quality and costs of supply. As an alternative, a shared ownership of the operation with the biomass producer can reduce the supply chain risks. As regards the ownership, when high investment costs and complex permitting procedures are required (i.e. in the case of DH networks), a public–private partnership can highly facilitate the operation, while BOOT contracts can be attractive for both the ESCO and the customer in case of lower investment costs (only heat generation and concentrated loads). In order to reduce the investment risk for the ESCO, some costs can be in charge of the customer, such as part of civil works or heat exchangers connected to a DH network to deliver energy to final end-users. The Energy Supply Contract with a fixed discount on the baseline energy cost for the customer is the simplest and more frequently implemented repayment strategy, which guarantees both the cash flows for the ESCO and the cost savings for the end-user, even if not encouraging energy efficiency. The billing strategy can be based totally on consumption charge in case of high heat rate and low demand fluctuation level

Table 4
Summary of main key factors influencing the feasibility of the proposed ESCO operations.

Supply-related factors	
Biomass supply	The control of costs, quality level and reliability of biomass supply are important key factors. Specific biomass supply contracts are put into practice by ESCO to secure their operations. Among the others, these contracts specify the biomass quality levels, price ranges, delivery methods and timing of supply
Reliability of technologies	Biomass combustion in high efficiency boilers is a reliable technology. Boilers coupled to ORC cycles for cogeneration are also reliable technologies, the main drawbacks being the high heat/electricity ratio and low electrical efficiency. For this reason, biomass CHP by ORC is profitable only in presence of high on site heat demand. Biomass gasifiers coupled to ICE, dual fuel MT (natural gas-syngas), or EFGT (externally-fired gas turbines) fired by natural gas and biomass can be interesting options to increase electrical efficiency and reduce heat/electricity ratio, mainly for small scale power generation
Flexibility of plants operation	Biomass plants are not as flexible as natural gas plants in varying the energy output to follow the demand. In some cases, peak natural gas boilers are used to match the load. Moreover, in the case of ORC based CHP plants the heat/electricity ratio is fixed and these plants can not participate to the power system balancing or modulate their power output to meet peak electricity demand. In these cases, thermal storage could be an option to increase plant operational flexibility
Financing issues	Large up-front capital costs and high risks deter investment by ESCO, in particular in case of CHP and expensive DH; on the other hand, public bodies lack the experience and financial capital for developing the infrastructure required. Public–private partnerships are hence required, which is a contributing factor leading to the slow growth in CHP-DH schemes
Demand-related factors	
Heat load rate	High and constant heat load rate is the main factor influencing the feasibility of biomass heating ESCO operations. For this reason, industrial and tertiary sector customers are commonly preferred to residential ones (mainly in case of mild climate areas). The presence of anchor loads (high heat demand and constant heat load profile) is determinant in the investment decision process. In particular, CHP plants are often built at the premises of anchor loads and their size and DH network lengths are successively increased when connecting further loads. The presence of cooling demand for refrigeration and air conditioning, in particular in the tertiary sector, can increase the heat load rate, when using adsorption chillers fired by biomass boilers. This can be a game changer for customers such as hospitals, leisure and sport centers, supermarkets, schools and offices
Baseline cost energy and tax levels	ESCO approaches are more likely to be implemented when the energy cost savings potentials are large, such as where gas network is missing, and expensive and not environmental friendly fuels (diesel, heavy oils) are used. On the contrary, end-users entitled for low tax rates on natural gas are less promising for a shift to biomass fuels (it is the case of industrial or tertiary sector customers, according to Italian regulations)
Baseline conversion efficiency	ESCO approaches are more likely to be implemented when the technical potential for energy cost savings are large, such as in case of low baseline conversion efficiency levels, old or not properly dimensioned energy infrastructures
Amenity issues	Air emission levels, noise, space availability for storage and biomass transport constraints are the main technical barriers towards the use of biomass for heat and power, in particular for tertiary and residential customers
On site biomass availability	The availability of biomass at the premises of energy end users (i.e. agro-industrial and wood processing firms) can be a game changer for the development of some biomass ESCO operations.
Number of end-users	Customer transactions and inertia costs are major bottlenecks in case of several small end-users served by the biomass plant, such as in DH schemes for residential sector
Social acceptability	The social acceptability is often one of the main constraints in the development of biomass heating and CHP projects, in particular in case of scarce information of the local communities about conversion processes, environmental impacts, biomass supply chains organization and socio-economic-environmental benefits of these investments. Public perception is a major issue in particular when biomass plants are integrated into urban energy infrastructures
Policy framework	
Subsidy for renewable energy	Specific subsidies for biomass based heat and power generation are required for a profitability of the investments. This is particularly true in the case of electricity generation, where the availability of feed-in tariffs or other market-driven support systems is required to develop biomass to electricity routes. However, in the case of only heat generation, and in cases of low biomass supply costs and high baseline energy costs, bioenergy could be competitive with fossil fuels without specific incentives
Policy for distributed generation	Distributed and on site generation is a mandatory requirement in case of biomass to energy routes, since the heat generated must be on site consumed by local end-users. This is particularly true in case of power generation, where the use of waste heat is determinant to achieve acceptable process efficiencies and use sustainably this renewable but limited resource. Transmission and distribution use of system charges should reflect the benefits of local power generation and simplified permitting procedures should be available for on site generation
Grid connection for power plants	Grid connection of small-scale CHP plants can be both expensive (depending on location of the plant) and complex for the permitting procedures required, and this is one of the main barriers towards the implementation of decentralized bioenergy projects
Permitting issues, planning constraints	Permitting procedures, in particular for district heating networks and biomass CHP plants located in urban areas, can be very complex and represent a major drawback for biomass ESCO operations

(i.e. industrial or tertiary sector). In the case of residential loads, a capacity charge should be included in the billing, to secure the cash flows. As regards the scope of supply, it should include the total heat demand of the customer; this means that the ESCO should operate biomass or gas fired back up boilers to match the peak loads and implement thermal storage systems or demand side management techniques to minimize the heat generation costs. The O&M should be as possible under the control of the ESCO, with performance guarantees and shared equity provided by manufacturers of specific high-tech parts of the plants (i.e. boiler, gasifiers or turbines).

6. Conclusions

The paper described biomass-ESCO approaches and business models for biomass heating and CHP generation. State of the art, policy measures and main technical and non-technical barriers towards the implementation of such ESCO operations at EU level and in Italy were discussed. Moreover, on the basis of the proposed framework, the paper explored the case for investment in biomass technologies using an ESCO approach in the Italian scenario. The financial viability of biomass heating and CHP investments for three market segments was assessed. This allowed exploring under which conditions and for which possible applications/market segments the ESCO approach could be more appropriate and less likely to incur in some of the non-technical barriers mentioned. All the case studies were referred to a 6 MWt wood chips fired thermal plant. The case study 1a regarded a dairy firm where the high thermal energy load rate makes particularly profitable the ESCO approach; the option 1b (biomass CHP) resulted also very profitable, even if presenting lower IRR than case 1a. The higher investment cost and the uncertainties in the feed-in tariff for bioelectricity resulted the

Table I.1
Main technical parameters of the proposed case studies.

	1a	1b	2a	2b	3a	3b
Thermal power (kW t)[a]	5,800	5,800	8,000	8,000	8,000	8,000
of which back up power (kWt))[b]	–	–	2,000	2,000	2,000	2,000
Electrical power (kWe)[c]	–	997	–	997	–	997
Thermal efficiency (%) [102,109]	90%	65%	90%	65%	90%	65%
Electrical efficiency (%) [103,110]	–	24%	–	24%	–	24%
Operating hour—electricity (h/yr)	–	7500	–	7500	–	7500
Biomass consumption (t/yr)[d]	15,450	18,907	5,979	13,920	4,305	13,000
District heating length (km)[e]	–	–	0.8	0.8	6.5	6.5

[a] Nominal thermal output power of the plant.
[b] A natural gas back up power is assumed, as described in I.2.
[c] Gross rated electrical power of the plant.
[d] Calculated according to biomass characteristics of Table I.3.
[e] District heating length is calculated assuming a district heating unitary length of 0.8 m/kW in the case of residential heat distribution [111] and an hypothetical distance of 800 m between thermal biomass plant and hospital; the DH losses are assumed 20.8 kW t/km (supply temperature 90 °C, return 50 °C, ground 5 °C, energy losses of 0.40–0.35–0.25 W/m K respectively for transmission, distribution and sub-distribution lines) [100–103], the DH electricity consumption is 15 kWe/km [101,102].

Table I.2
Main economic parameters of the proposed case studies.

	1a	1b	2a	2b	3a	3b
Investment costs for ESCO (kEur)[a]	816	4,623	1,294	5,103	3,351	7,785
of which biomass plant cost [105,106,112,113]	816	4,623	840	4,187	720	4,187
of which district heating cost [93,94][b]	–	–	304	304	2,481	2,481
of which back up boiler cost [105,107]	–	–	150	150	150	150
Investment cost for client[c]	50	50	100	100	570	570
Operational costs for ESCO (kEur/yr)[d]	1,110	1,647		1,406		1,329
Type of baseline fuel [e]	HO	HO	NG-t	NG-t	NG-r	NG-r

[a] The biomass CHP and biomass boiler specific costs are assumed respectively 4200 kEur/MWe and 140–120 kEur/MWt for 5 (case 2 and 3) and 12 (case 1) bar boilers; the specific cost of natural gas back up boiler is 75 kEur/MWt; in case of CHP, the investment cost includes the biomass integration boiler.
[b] The district heating cost is assumed 380 kEur/km, while the heat exchanger and district heating connection costs are in charge of the end users.
[c] The investment cost for client is represented by part of the civil works for biomass boiler installation at the premise of the client (in case 1), and heat exchangers costs in case 2 and 3. These costs are covered by the end-users as initial fees of the heat service contract with the ESCO.
[d] The operational costs include: (i) the biomass supply costs, (ii) the natural gas cost for back up boiler (as from Table I.3); (iii) the maintenance, ashes discharge, additives, management costs (assumed 3,5% of investment cost; (iv) personnel work (5 persons for a total of 185 kEur/yr), (v) electricity costs for district heating pumping.
[e] HO: heavy oil; NG-h: natural gas for tertiary sector; NG-r: natural gas for residential sector.

Table I.3
Fuel techno-economic parameters of the proposed case studies.

	LHV	Cost
Biomass[a]	2.93 MW h/t	70 Eur/t
Natural gas-ESCO (NG-E)[b]	9.59 kW h/N m^3	38 Eur/N m^3
Natural gas-hospital (NG-t)[c]		48 Eur/N m^3
Natural gas-residential (NG-r)[d]		80 Eur/N m^3
Heavy oil (HO)	9,700 kcal/kg	400 Eur/t

[a] Wood chips with moisture content of 35% and LHV of dry matter of 4,200 kCal/kg; biomass cost at power plant included transport [85,86].
[b] Natural gas supply cost for ESCO.
[c] Natural gas baseline cost for tertiary sector (hospital) [118].
[d] Natural gas baseline cost for residential end users [117].

main barriers for this option. In case 2, where heat is provided to a hospital, the profitability of ESCO approach resulted also high, since the lower heat load rate (25% in comparison to 80% of case 1) is partially balanced by the higher baseline energy cost (hence higher thermal energy selling price for the ESCO). Case study 3 regarded the heat service in residential sector by means of biomass plant and district heating network. In this case, the profitability of the investment for the ESCO resulted the lowest (IRR around 12–13%) because of the low heat load rate and the high investment cost for the DH network, partially balanced by the highest heat selling price.

In conclusion, biomass heating resulted very profitable in case of high heat load rates and high fossil fuel costs. In the case of residential and tertiary sector the heat distribution costs and the heat demand intensity are key factors. The CHP option requires higher investment costs and presents longer bay back times. The baseline fossil fuel cost, efficiency level and the fuel tax level can also make the difference, and the subsidies from White certificates mechanism can provide an important (even if not determinant) contribution to the feasibility of the investments. Biomass cost and involvement of ESCO in the biomass supply chain are also key factor. Further barriers towards the development of these business models are: the access to loan, attitude of end users, permitting issues (in particular in residential and tertiary sector), logistic and amenity issues (storage, particulate air emissions, transport constraints, public perception). Moreover, energy price volatility creates uncertainty over the cost of fuel being purchased and energy being sold; this in turn makes it difficult for risk adverse local CHP-DH developers to determine the profitability of a scheme over long periods. Uncertainty over future regulation within the energy sector limits long-term investments and encourages conservative short-term, quick profit decision-making. Biomass CHP-DH competes directly with natural gas, yet the tax on gas used for tertiary sector heating (i.e. hospitals, leisure and sport centers) is only a quarter of that charged for domestic use in Italy, so reducing the relative profitability of biomass CHP-DH for these promising customers (anchor loads). Several important design recommendations for improving the economics of CHP-DH include the appropriate use of system balancing techniques using heat accumulators, trigeneration using chilled pipe networks, variable heat to power ratios and the use of variable volume flow rates in heat networks.

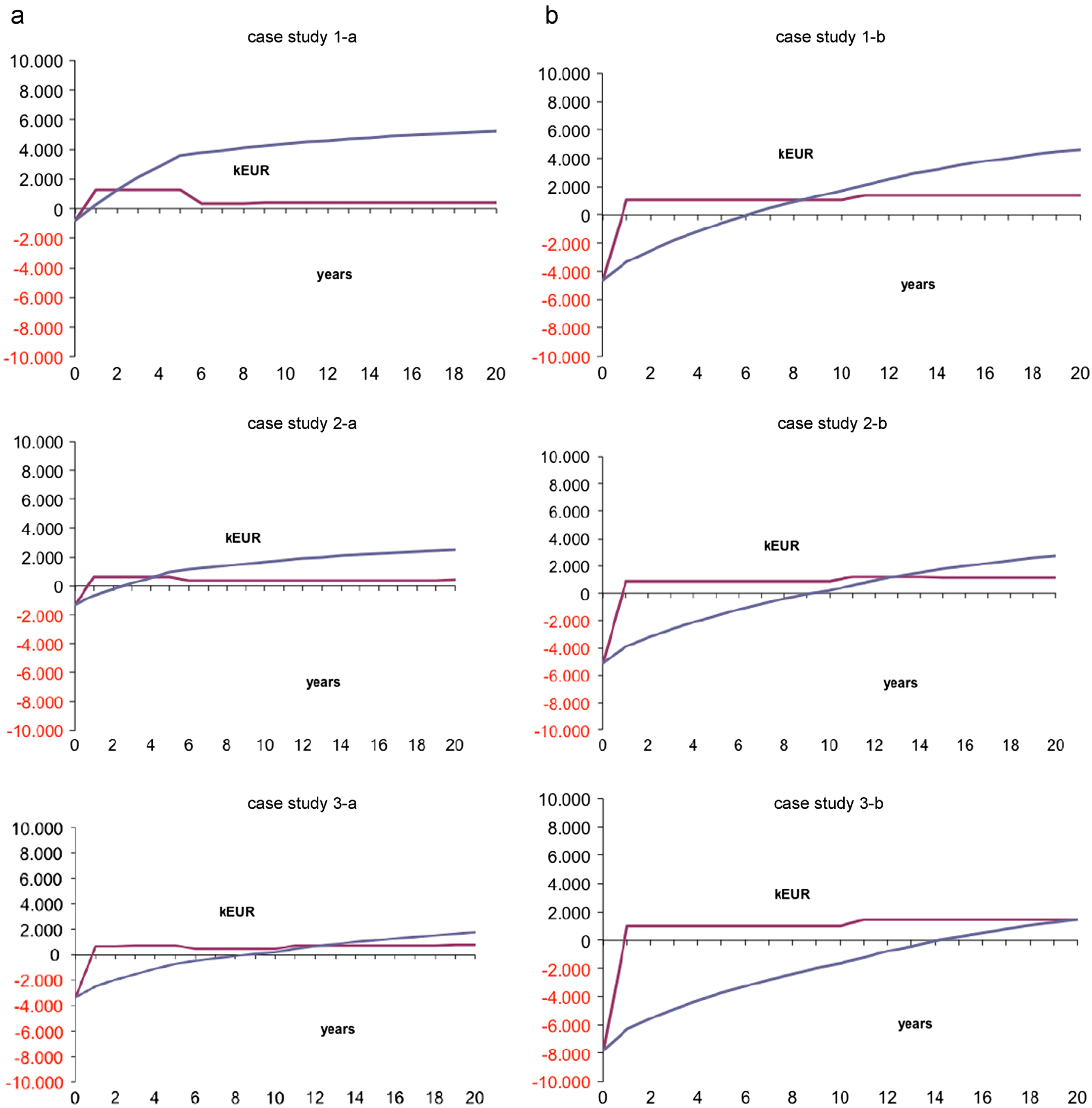

Fig. II.1. Net present value and cash flows of investment for the three case studies, with cogeneration (b) and without cogeneration (a). .

However, some of them (variable heat/power ratio and flexibility of energy output) can be hardly implemented in case of biomass generators. As regards involvement of public sector into biomass-ESCO business models, the reform of public procurement procedures to encourage energy services contracting appears the most important initiative to be pursued.

The results of this study can contribute to: (i) selecting end-user segments and particular conditions where the ESCO approach to biomass heating and CHP could be more promising, (ii) selecting the optimal business model for each market segment, (iii) defining the main technical and non technical barriers towards the biomass ESCO business in Italy; (iv) proposing policy measures to overcome these bottlenecks and facilitate the diffusion of biomass heating contracts.

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Annex I. Hypothesis for techno-economic comparisons

I.1 Investment and operational costs for the proposed case studies

The capital cost of equipment has been estimated from a combination of process modelling, in-house data and industry information. This has been adjusted to reflect total development cost in line with existing experience in Italy. Operating costs have been calculated based on an understanding of staffing patterns, plant consumables and typical maintenance and administrative requirements. Biomass costs have been quantified on the basis of typical current prices for Italy. Power production in the case of CHP has also been assessed from the process modelling and benchmarked assessments of capacity factor based on commercial plant performance.

The main technical and economic parameters for the investment appraisal are reported in Tables I.1,I.2. In addition, the following financial assumptions have been taken: (i) 20 years of operating life; no 're-powering' throughout the 20 years; zero decommissioning costs; (ii) maintenance costs and biomass supply costs increased by a annual rate of 1%; (iii) heat selling price increased by a annual rate of 1%, according to personal estimates based on natural gas market projections in Italy [106–108]; electricity selling price (feed-in tariff) held constant (in real 2012 values) for the 20 years lifetime of the plant; (iv) capital assets are depreciated using a straight line depreciation over 10 years (except for the case 1a and 2a, where a 5 years depreciation period is assumed); no equity; (v) the cost of capital (net of inflation) equal to 10%, corporation tax neglected, capital investments and income do not benefit from any support.

I.2 Back up boilers and CHP sizing

The annual operating hours at rated power of the thermal plants are commonly assumed on the basis of the typology of processing technology, plant size and energy load demand. In the proposed case studies, the thermal plants operating hours are taken equal to the heat factor of the loads. However, in case of highly variable heat demand patterns and low yearly operating hours (such as in case studies 2 and 3), it is common practice to install gas-fired back up boilers in order to increase the conversion efficiency of biomass boilers (that can thus operate at rated power for an higher number of hours) and reduce the overall investment costs [48,97]. In the proposed approach, natural gas fired back-up boilers are introduced for the case studies 2 and 3; their nominal size is equal to 25% of the peak thermal energy demand. Moreover, it is assumed that 20% of the total annual thermal energy is produced by back up boilers, with conversion efficiency of 75%.

The optimal CHP sizing is also based on several factors [115,116], such as the thermal and electrical load patterns, the cost of fuels (both biomass and back up fuel), the electricity and heat selling prices, the relative efficiencies of back up boilers and CHP plants, the specific investment costs and economies of scale. There are three ways to design and operate CHP-DH network [38,48]: (i) summer heat lead system with back-up boilers accommodating peak winter demands, (ii) winter heat lead systems, (iii) electrically lead systems enable the CHP unit to operate at times of peak power demand and maximize the revenue generated from the electricity. The first strategy is the most common and risk free approach, with the drawback that total CHP heating capacity is minimized and the amount of electricity that can be produced is reduced. The second approach presents unused heating capacity during summer months, despite CHP can provide heat for the majority of winter demand. In the third case, heat sinks within the system are required so that heat can be stored for later use. This system may also need back-up heating systems such as boilers when it is not economical to produce electricity or when heat demand exceeds CHP capacity.

In the proposed case studies, a size $P_{el,CHP}$ of 1 MWe for the CHP plant is assumed, and the related thermal power $P_{th,CHP}$ is calculated by means of Eq. (1), being $\eta_{th,CHP}$ and $\eta_{el,CHP}$ the thermal and electrical efficiency of the plant. The thermal energy demand of the load is matched by means of biomass integration boilers and natural gas back up boilers, according to the same assumptions of the case of only heat generate

$$\frac{P_{th,\ CHP}}{\eta_{th,\ CHP}} = \frac{P_{el,\ CHP}}{\eta_{el,\ CHP}} \tag{1}$$

The operational mode of CHP plant is assumed base load (7500 h/yr), which means that the plant is in operation for the maximum number of hours compatible with scheduled and unscheduled maintenance, in order to maximize the electricity generation.

I.3 Biomass and fossil fuel costs assumptions

The *baseline fossil fuel cost* is a key factor for the profitability of biomass ESCO operations. It is dependent on the type of fuel, the specific typology of end-user, geographical area, annual consumption, fuel tax rates. The reference costs of natural gas for small residential end users resulted 87.92 Eur/N m^3 (AEEG data, April 2012 [117]) (AEEG also regulates the natural gas bill for residential end-users]). However, in case study 3 a baseline cost of 80 Eur/N m^3 is assumed (valid for residential blocks with consumption below 200,000 N m^3/yr, eligible for fuel tax reductions [119]). In the case of hospitals, cost data range between 35 and 70 Eur/N m^3 [118] according to type of end-user, tax level applied and gas contract typology. In case study 2, a conservative cost of 48 Eur/N m^3 (VAT excluded) is assumed, that takes in account the fuel tax rate reduction available for this typology of end-users [120,121]. Cost figures for heavy oil fuel are taken from the diary firm case study (VAT excluded). The thermal efficiency of the existing fossil fuel plants, required to estimate the baseline thermal energy cost for the client, is assumed 85% in all the case studies [114].

Annex II. Net present values and annual cash flows of the proposed case studies

See Fig. II.1.

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